Final Report to the
Alfred P. Sloan Foundation

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Table of Contents

1. Summary of Scientific Results

The principal scientific goal of the Sloan Digital Sky Survey (SDSS) was to gather the data necessary to gain a comprehensive understanding of the large-scale three-dimensional distribution of galaxies and quasars, and to use this as a probe of models for the overall structure, geometry, and evolution of the Universe. This goal was realized: the SDSS imaged hundreds of millions of astronomical objects and acquired spectra of close to a million objects, all calibrated to a much more precise level than had been achieved before. Such voluminous, uniform, and precise data allowed studies that have affected almost every area of astrophysics.

The Legacy of SDSS Data

June 30, 2005 marked the end of the observing period for the SDSS. Through June 30, the footprint area of sky covered by imaging was approximately 9500 square degrees (combining both the main survey and the new SEGUE survey). A total of 1567 unique "tiles" were observed spectroscopically, including 1278 for the primary survey area. Counting each fiber as being a spectrum of a unique piece of sky, at 640 fibers per tile, the survey obtained approximately 1 million spectra.

The brightnesses of the objects cataloged in the imaging survey were calibrated in five different filters to 2% accuracy, meeting the specifications. The positions of stars and galaxies were calibrated to better than 0.1 arc seconds. The spectroscopic survey is similarly characterized by high precision in the spectroscopic redshifts, in the reliability of the spectroscopic classifications, and in the quality of the spectrophotometric calibration.

The imaging and spectroscopic surveys are each by far the largest such efforts ever undertaken. The data are publicly available in searchable databases and flat files (http://www.sdss.org/dr4). In addition to the formal data releases, derived catalogs have been produced of objects such as quasars, clusters of galaxies, and white dwarfs, which greatly facilitate research on the statistical properties of the respective classes. The final SDSS data release, DR5, will be made public after the most recent data have been calibrated and validated. The SDSS set a high standard for the functionality of large astronomical databases.

Approximately 800 papers have been published in the refereed astronomical literature, roughly half of which were written by astronomers outside the SDSS collaboration. These papers have had a substantial impact: 40 have been cited 100 or more times, a standard criterion for an influential paper. The SDSS data provide a basic reference for an array of satellites, including the *Hubble Space Telescope*, the *Spitzer Space Telescope*, and the *Ultraviolet Galaxy Evolution Explorer*. The SDSS photometric system is being used on major telescopes all over the world. In addition, the SDSS has helped to motivate the next generation of large surveys: projects such as the Large Synoptic Survey Telescope, Pan-STARRS, and LAMOST look directly to SDSS for technical, managerial, and scientific guidance as they build the surveys that will eventually surpass SDSS itself.

The scientific impact of the SDSS has been acknowledged by the astronomical community in several ways. For example, in December 2003, *Science* magazine highlighted SDSS results in large-scale structure in their assessment of the most important science breakthrough of the year. Jim Gunn, SDSS Project Scientist, was recognized with the Henry Norris Russell Lectureship, the Peter Gruber Prize in Cosmology, and (jointly with Jim Peebles and Martin Rees) the Crafoord Prize awarded by the Royal Swedish Academy of Sciences, in large part for the successful outcome of the SDSS. Young astronomers who have made their careers working on SDSS data have been offered faculty positions at institutions such as University of California Santa Cruz, University of Washington, Lawrence Berkeley Laboratories, University of Arizona, Portsmouth University, MIT, and many others.

The Large-Scale Structure of the Universe

The distribution of galaxies encodes information imprinted from the early universe, soon after the Big Bang. Detailed study of the galaxy distribution reveals physical processes taking place when galaxies formed and even earlier. The observed galaxy distribution also depends on the overall geometry of the universe, its expansion rate, and its matter and energy content.

The SDSS data comprise three redshift surveys: a magnitude-limited sample of galaxies, probing to a distance of 2.6 billion light years; a substantially deeper but sparser survey of luminous elliptical galaxies, which samples the galaxy distribution to 5 billion light years; and a sample of quasars which spans almost all of the volume of the visible universe. Absorption lines in the quasar spectra reveal the distribution of intergalactic gas filaments. Images of galaxies and quasars are distorted by the gravity of foreground objects, allowing a direct measurement of the mass associated with these objects.

SDSS astronomers have exploited these various techniques to trace the large-scale structure of the universe. The analysis is inherently statistical, and a variety of tools have been used. For example, a series of spheres of a given radius (say, 40 million light years) are placed at random in the universe, and the galaxies in each are counted. Because galaxies are clustered, that number will fluctuate from one sphere to another; the value of the fluctuation amplitude is the scatter of the galaxy counts around the mean value. Carrying out the same exercise with spheres of a variety of radii determines the magnitude of these fluctuations as a function of scale size, and the resulting quantity is the *power spectrum*. Because of the large volume surveyed, and the careful control of systematic errors, the power spectrum determined by the SDSS extends to larger scales than measurable with other surveys.

The power spectrum depends in interesting ways on both the overall geometry of the universe and on its contents, including how much dark matter, dark energy, ordinary matter, and neutrinos it contains. The SDSS has made the definitive measurement of the galaxy power spectrum, as well as the best measurement to date of the power spectrum inferred from the absorption lines in the spectra of quasars (which allows clustering to be measured on smaller scales than with galaxies). When these measurements are combined with other diagnostics, especially the fluctuations in the early universe seen by the Wilkinson Microwave Anisotropy Probe (WMAP), the results are in excellent agreement with the standard cosmological model. From this model we can infer:

- The universe is geometrically flat, a result precise to a few percent.
- Thirty +/- 4% of the energy density of the universe is made up of matter. Only about 15% of that amount is baryonic, the rest being dark matter, whose physical nature remains mysterious.
- The remaining 70% of the energy density is termed *dark energy* and is responsible for causing the expansion of the universe to accelerate. The SDSS measurement of the integrated Sachs-Wolfe effect, whereby the imprint of the present-day distribution of galaxies is seen on the cosmic microwave background, gives independent evidence for the existence of the dark energy.
- The dark matter is not made up of neutrinos. SDSS measurements, especially from the quasar absorption lines, put tight constraints on the mass of any neutrino component.
- The overall shape of the power spectrum is in excellent agreement with that predicted by the standard Big Bang model, together with the inflationary paradigm which seeks to explain the overall flatness and isotropy of the universe. The very precise SDSS results have ruled out interesting deviations from the simple inflationary predictions.

The cosmological picture requires that with time, gravity enhances the degree of clustering of the matter. This basic expectation has been confirmed in another SDSS result, in which specific features in the power spectrum of the cosmic microwave background (a consequence of sound waves propagating through the early universe) are seen to be mirrored in the distribution of luminous elliptical galaxies.

Quasars

Material flowing into a supermassive black hole heats up and radiates much more energy than does the host galaxy itself. Such quasars are so luminous they can be seen to enormous distances and are among the most distant objects known. The SDSS has been particularly successful in identifying the most distant quasars, discovering the 19 highest-redshift ones, at redshifts up to 6.4. The formation of these supermassive black holes appears to be an integral part of the formation of galaxies.

Quasars are seen through tenuous hydrogen and helium gas that is ubiquitous in the intergalactic medium. Clumped neutral hydrogen is easily detected via absorption in the Lyman alpha line. Since hydrogen has such a high cross section to this absorption, restrictive upper limits can be placed on the amount of diffuse neutral gas (the Gunn-Peterson effect). The small amount of neutral hydrogen allowed by the data suggests that there was a source of ultraviolet light at early epochs, perhaps the first generation of stars, that re-ionized much of the intergalactic gas. If one could find a quasar that was at a redshift so high that it preceded the earliest sources of ionizing radiation, then one might expect to see the characteristic absorption due to the diffuse neutral hydrogen in the intergalactic medium.

Exactly this effect has been seen in the spectra of the highest-redshift quasars detected by the SDSS. The data show that at least 0.1% of the hydrogen is neutral 900 million years after the Big Bang. The hot electrons released when the hydrogen is ionized scatter and polarize the photons of the Cosmic Microwave Background. The WMAP satellite has measured this effect, and the WMAP team claims that the universe made the transition from neutral to ionized about 200 million years after the Big Bang. The results from WMAP and SDSS suggest that reionization may have been a several-step, drawn-out process, contrary to earlier expectations.

Individual quasars show remarkably similar properties even when observed at very different redshifts or cosmic epochs. However, it has long been known that the *population* of quasars changes dramatically with redshift. Luminous quasars were common in the universe at a redshift of 2 to 3, corresponding to roughly 11 billion years ago. They were less common at redshifts greater than 5, and are even rarer at the present epoch. SDSS has provided excellent statistical leverage to study such evolutionary changes in detail. For example, SDSS discovered that the ratio of less luminous quasars to those of the highest luminosity is larger recently than it was in the distant past, which may reflect a systematic change in the accretion rate depending on cosmic epoch and host galaxy properties.

For very nearby quasars, we can do even more detailed studies, and ask for the relationship between the central black holes and the galaxies in which they live. While luminous quasars are rare nearby, less luminous objects are relatively common, and SDSS results have shown for the first time a smooth transition between the two. Active black holes are typically found in galaxies with evidence of recent star formation, and that activity tends to be strongest in (relatively rare) massive blue galaxies.

There has been increasing evidence that many quasars are hidden from view by obscuring clouds of dust in their host galaxies. SDSS data have revealed such objects despite the obscuration, and the catalogs comprise by far the largest sample of obscured quasars. It has been particularly fruitful to follow up these objects using satellites in the X-ray (*Chandra* and *XMM-Newton*) and in the far-infrared (*Spitzer Space Telescope*), studies that confirm their very high luminosities.

Galaxies

The SDSS gives enormously detailed information on galaxies: for each of over half a million objects, the database includes measurements of their brightness in five filters, their distance, measures of the stars that make them up, their central dynamics, their chemical composition, the amount of dust, and their large-scale environment. With this plethora of data on so many objects, the SDSS has explored the full range of galaxy properties to a far greater level of detail than was ever possible before. The SDSS data have become even more powerful for galaxy studies when combined with surveys at other wavelengths, including the near-infrared, mid- and far-infrared, radio, ultraviolet, and X-ray. The improved understanding of ordinary galaxy properties has been especially useful in interpreting very distant galaxies observed by much larger telescopes: direct comparisons can now be made between galaxy populations in the early universe to those today, showing how the one evolves into the other.

Galaxies come in elliptical and spiral types, but we now know with far greater precision the relationship between these morphological types and the colors of the galaxies. Understanding the types of stars which make up the galaxies from the spectra allows us to determine the total mass of the stars in each galaxy. Galaxies with stellar masses more than about 30 billion times that of the Sun tend to be made almost exclusively of old stars, and have an elliptical shape, while lower-mass galaxies are more likely to be dominated by a disk and to be actively forming stars.

There is also a correlation of mass with the chemical composition (metallicity) of the galaxy. At masses below 10 billion solar masses, galaxies show a linear trend with metallicity; the higher the mass, the higher the metallicity. However, above 10 billion solar masses, the trend flattens, and all galaxies have roughly the same metallicity. This trend is exactly as predicted in models where low-mass galaxies lose their metals in winds from supernovae, while in high-mass galaxies such winds do not have enough kinetic energy to escape.

Galaxies in relatively dense environments such as the cores of rich clusters of galaxies tend to be massive, old stellar systems, while galaxies without close neighbors tend to have lower masses, a higher fraction of mass in their interstellar media, and on-going star formation. The existence of a connection between present-day galaxy properties and their environment has been known for some time, inspiring much effort to determine the detailed physical processes in play. The SDSS catalogs of galaxies have, as originally anticipated, been extraordinarily powerful in enabling such studies, which bear on how luminous matter settled into the clumps of dark matter on both small and large scales.

It has long been known that galaxies are surrounded by substantial quantities of dark matter. However, astronomers have had only a few handles on how the dark matter is distributed. SDSS measured the effects of weak lensing (the systematic distortion of distant galaxy shapes due to the gravity of foreground objects) by nearby galaxies. This work provided the most complete measurement to date of the extent of dark matter halos on scales from 80,000 light years to 30 million light years. The dark matter halos follow the same distribution as that of the galaxy correlation function, implying no dramatic change in the ratio of luminous matter to dark matter as a function of scale. The halo masses do depend on galaxy luminosity, in a way that is at least in rough agreement with a constant ratio of luminosity to dark matter.

The Structure of the Milky Way

SDSS data can be used to study structure traced by stars in the Milky Way. The earlier picture of the Milky Way consisted of a central bulge surrounded by a flattened disk with spiral arms, with a smooth and spherical halo of old stars enveloping the disk. However over the past few years, motivated in part by discoveries from the SDSS, astronomers have realized that the halo is not smooth, but has structure. Theorists had predicted that galaxies grow by merging with small companions, and there was some evidence that the Milky Way was no exception to this. The results of these encounters were expected to be a series of trails of stars criss-crossing the halo, each the remnant of a galaxy which had been swallowed by the Milky Way. Accurate maps of the distribution of stars stretching across the sky are required to find such star streams. SDSS astronomers discovered a stream of stars which appears to wrap completely around the Milky Way, drawn out from the Sagittarius dwarf galaxy. It is clear that its stars are being incorporated into the halo of the Milky Way. The Sagittarius stream is now one of several stellar trails apparent in the SDSS data; collectively they can reveal the extent to which the entire Galactic halo may have resulted from such dynamical encounters.

Another example of a stellar stream has been seen from a globular cluster, Palomar 5, which also appears to be in the process of being torn apart by tides from the Milky Way. The SDSS finds a faint scrim of stars clearly associated with the globular cluster, stretching across 20 degrees of sky. As this globular cluster plunges through the disk of the Milky Way every few tens of millions of years, more stars get torn away, leaving a long trail behind. This result suggests that the Milky Way used to have many more globular clusters than the hundred or so currently known, the remainder having been dispersed in the distant past.

Several extremely low-luminosity galaxies have been found neighboring both the Milky Way and the Andromeda galaxy; these new discoveries are perhaps the lowest-luminosity galaxies ever seen. Theoretical models of galaxy formation predict more low-luminosity galaxies than are readily apparent in surveys. The SDSS data in Andromeda may point to some of this previously missing population.

Stars

Any star less massive than roughly one tenth that of the Sun does not have the gravity necessary to raise the core temperature to the point that thermonuclear fusion can take place. Astronomers have been searching for such "failed stars," or brown dwarfs, for decades. The search is not easy: brown dwarfs are very faint, with most of their radiation emerging in the infrared. The first discoveries of substantial numbers of such objects came with the Two Micron All-Sky Survey (2MASS) in 1998; the SDSS followed soon thereafter. For temperatures below 2200 K, vanadium oxide and titanium oxide solidify and rain out of the atmosphere. The spectra of these cooler objects show absorption from alkali metals such as potassium, rubidium, and cesium, as well as hydrides of iron, chromium, and calcium. The spectra look very different from those of the warmer M-type stars, and thus these objects are given a different classification: the L dwarfs. At even cooler temperatures, below roughly 1300 K, the chemistry changes again. Carbon, which is preferentially locked up in CO in M and L dwarfs, now combines with hydrogen to make methane. These objects are known as methane or T dwarfs. Theoretical calculations show that there is only a narrow range of temperatures at which both carbon monoxide and methane co-exist in a stellar atmosphere, yet SDSS discovered several such transition objects.

Other unusual stars have a large quantity of carbon in their atmospheres. These carbon stars are generally thought to be the result of nuclear helium burning to carbon, which is transported to the surface of the star by convection, or perhaps dumped onto the surface by a close binary companion. The SDSS has discovered large numbers of carbon stars by virtue of their strange colors. Many of these objects seem to be unevolved dwarf main sequence stars which could not have made the carbon in their interiors, and thus have probably been contaminated by the explosion or eruption of a former companion. Hotter examples have also been found, stars of about the temperature of the Sun, which also have carbon molecules in their atmospheres. At the temperatures of these stars, all carbon should be in atomic form unless there is a truly enormous overabundance of carbon, the origin of which is still mysterious. The velocities of these hot carbon stars suggest that they belong to the old stellar halo of the galaxy, a result that may help understand their origin.

The SDSS is the first survey to discover degenerate stellar remnants (white dwarfs) over their full range of properties (surface temperature, surface chemical composition, and variability). A catalog of several thousand of them, more than the total known to date, allows definitive measurements of the relative numbers of these different types. These data constrain models of white dwarf formation and the history of star formation in the disk of the Milky Way.

One particularly interesting star discovered in the SDSS is rocketing out of the center of the Milky Way, moving at 700 km/s, fast enough to escape completely. It is thought that this star was ejected in a gravitational encounter with the supermassive black hole at the center of the Milky Way, and is the first example of this phenomenon ever seen.

Asteroids

The SDSS imaging camera surveyed the sky in five filters, where the exposure in each filter is shifted by about a minute from the next. The image of a moving object, such as an asteroid, is thus offset slightly in each of the filters. The SDSS software recognizes this characteristic motion. The SDSS precisely measured the colors of some 100,000 asteroids, more than one hundred times the number with such data available beforehand. Asteroids can be classified by their orbital parameters: semi-major axis, eccentricity, and inclination. Plots of these quantities for all known asteroids show clumps with similar orbits, termed *families*. It has long been suggested that the members of a family are shards of a larger single body that was broken up in a collision earlier in the history of the Solar System. If this is the case, one would expect that the asteroids of a given family would share the same chemical composition and age and therefore would have similar colors. The SDSS data confirm this hypothesis dramatically: asteroids from common families tend to have similar colors, differing from those of other families. Asteroid colors are expected to evolve due to surface changes induced by space weathering, namely alteration of the surface composition by the solar wind and micrometeorite impacts. The observed colors and orbits agree with this hypothesis, and explain a long-standing mystery, that the colors of meteorite sections measured in the laboratory differ from those of common asteroids.

2. Summary of Financial Performance

The Sloan Digital Sky Survey (SDSS) received a grant award of $10,000,000 from the Alfred P. Sloan Foundation to support the observational period of the SDSS. The observational period began on April 1, 2000 and ended on June 30, 2005. Remaining work beyond the observational period involves preparing and loading data for the final SDSS public data release; this work will be completed by September 30, 2005.

Table 1 compares the actual cost of operations for the SDSS against the cost estimate contained in the grant proposal[1]. The original cost estimate was $24,000,000. The final cost is $26,205,655.

Table 1. Estimated and Actual Cost of the Operations Phase ($K)

Institution	Estimated Cost	Actual Cost
Fermilab	7,004	9,446
Apache Point Observatory	6,086	7,390
University of Washington	1,554	1,619
Princeton University	1,761	1,885
Johns Hopkins University	1,075	1,440
PT Automation	200	170
University of Chicago	1,142	662
U.S. Naval Observatory	1,060	580
Spectroscopic Scientist	359	70
Los Alamos National Lab	0	1,264
Japan Participation Group	0	97
New York University	0	19
Institute for Advanced Study	0	9
ARC Corporate	1,083	1,487
Contingency	2,674	25
Capital Improvements	0	43
Total	24,000	26,206

Table 1 presents costs organized by the participating institutions, in order to provide a direct comparison with the cost estimate presented in the proposal. The actual cost shown includes actual expenses through June 30, 2005 and a forecast of anticipated expenses for the period July 1 through September 30, 2005, when data collected during the last year of observing will be loaded into databases in preparation for the final data release.

The $24 million cost estimate consisted of $6.435 million in anticipated in-kind contributions from Fermilab, the U.S. Naval Observatory, and the Japan Participation Group; and $17.565 million to cover anticipated cash expenses. In-kind contributions exceeded anticipated levels by $2.967 million, while actual cash expenses were $761,000 less than anticipated. The net result is that the final cost of operations exceeded the cost estimate by $2.206 million, or 9.2%. The increase is best explained by reviewing in-kind contributions and cash expenses separately.

Summary of In-kind Contributions

Table 2 compares the actual value of in-kind contributions received against the cost estimate. The increase of $2.967 million is due in part to the inclusion of in-kind effort that was not included when the original cost estimate was prepared, and in part because we had underestimated the amount of effort required in some areas.

[1] Table 6.3, in: A Proposal for Operations Funds to the Alfred P. Sloan Foundation, September 1999.

Table 2. Anticipated vs. Actual Value of In-kind Contributions ($K)

Institution	Anticipated Value	Actual Value
Fermilab	5,375	7,460
U.S. Naval Observatory	1,060	580
Los Alamos National Lab	0	1,264
Japan Participation Group	0	97
Total	6,435	9,402

The following list summarizes the more significant elements associated with the increase in the in-kind portion of the final project cost.

1) The value of Fermilab in-kind salary support for survey management (the Project Manager and project management office) was not included in the original cost estimate. It was added to the project budget in 2000 in order to more accurately capture the cost of operations.

2) The level of effort associated with supporting and maintaining the observing systems at APO, and the data acquisition system, was greater than anticipated when the cost estimate was prepared. Much of the increased effort was provided by Fermilab as an in-kind contribution.

3) Los Alamos National Laboratory's long-term commitment and level of support was not fully defined when the cost estimate was prepared, so the cost estimate did not include Los Alamos support for survey operations. In fact, Los Alamos contributed significant resources during the 5-year operations phase in the form of in-kind support for observing software development and science testing.

4) Members of the Japan Participation Group participated in efforts to calibrate the SDSS imaging camera, and to develop a system to monitor for changes in calibration over time. The value of this effort was not included in the original cost estimate.

Table 2 also shows that the level of support provided by the U.S. Naval Observatory was roughly half of that originally anticipated. As operations progressed, it became apparent that the level of effort required from the U.S. Naval Observatory to support data reduction software and data processing operations was less than we anticipated would be necessary. Thus, although the level of effort provided was significantly less than anticipated, it was sufficient to meet project needs.

Summary of Actual Cash Expenses

Table 3 compares actual cash expenses to the cost estimate. Cash expenses exceeded the initial cost estimate by $1.888 million, before contingency. New demands against the cash budget were offset by re-allocating funds within the approved budget and drawing down the contingency. As a result, total final cash expenses were $16.804 million, or $761,000 less than the total cash budget of $17.565 million (estimated cash cost plus contingency).

Table 3. Estimated vs. Actual Cash Expenses ($K)

Institution	Estimated Cost	Actual Cost
Fermilab	1,631	1,986
Apache Point Observatory	6,086	7,390
University of Washington	1,554	1,619
Princeton University	1,761	1,885
Johns Hopkins University	1,075	1,440
PT Automation	200	170
University of Chicago	1,142	662
New York University	0	19
Institute for Advanced Study	0	9
Spectroscopic Scientist	359	70
ARC Corporate	1,083	1,487
Capital Improvements	0	43
Sub-total	14,891	16,779
Contingency	2,674	25
Total	17,565	16,804

The following list summarizes the more significant elements associated with the increase in the cash portion of the final project cost.

1) We increased the observing staff by one observer and established an Observers' Research Fund in response to an external review recommendation that addressed observer retention concerns. The addition of a lead observer improved communication between survey management and the observing staff, and made more time available for the observers to do research. The research fund covered travel expenses incurred by the observers in the course of their research.

2) Salary support for the Director was not included in the original cost estimate. At the time the proposal was prepared, the Director’s salary was being provided as an in-kind contribution, and in-kind salary costs for senior scientists were not included in the operations budget. When the new Director was appointed in 2003, the support agreement between the new Director’s host institution and ARC stipulated that a portion of the Director’s salary support be provided by the project in the form of cash payments. The final cost total includes the cost of this support.

3) We added one computer professional at Fermilab to support the SDSS web site and data distribution activities. We also added one additional year of computer professional support at The Johns Hopkins University for science database development and the funds to buy computer hardware to support the data distribution effort. The original plan was to have identified a partner who would ultimately take over responsibility for the long-term archive, and who would in the short term contribute resources to support data distribution activities. We did not succeed in identifying such a partner, and have thus borne the costs internally of the extra work.

4) We added an additional computer professional at Fermilab to support data processing operations. We had underestimated the scope of work involved in setting up the data processing operation to work in an efficient manner.

5) We added an additional computer professional at Fermilab to support observing software development. This provided the resources necessary to complete the software programs used by the observers to operate the telescope and instruments. The same individual developed the time-tracking tools that allow us to measure and track the performance and efficiency of observing operations.

6) We increased the level of support for data reduction software development, maintenance and support at the participating institutions. When the original budget was prepared, it was envisioned that the

development would finish within the first two years of operations and the level of support required for software maintenance would reduce substantially. Development efforts continued longer than we had anticipated and the level of effort to support the pipelines also proved to be greater than anticipated.

7) We added an additional electronics technician at APO to provide better maintenance and repair support for the telescopes, instruments, and associated hardware systems.

8) We improved office space at APO for the observers and the engineering staff by replacing single-wide temporary office trailers with double-wide units. The upgrade addressed serious overcrowding issues and increased employee morale substantially.

9) The cost for project teleconferences was not included in the original cost estimate. These costs were originally provided by Fermilab as an in-kind contribution but the value was not included in the baseline budget. Given the geographical dispersion of SDSS operations, teleconference charges became substantial during the first two years of operations. Consequently, Fermilab asked to be reimbursed for these charges and so they were added to the project budget and captured in the project cost.

10) Per the approval of the Advisory Council, we funded time domain studies designed to explore the feasibility of using the SDSS hardware for this purpose beyond 2005. These studies were the precursor to the Supernova project component of the 3-year extension.

As shown in Table 3, the initial amount set aside for contingency was \$2.674 million. \$1.913 million in contingency funds were allocated to cover increases in the cash cost of the project; the remaining \$761,000 in unspent contingency funds will be used to pay down unpaid invoices incurred during project construction, once final SDSS operations invoices are received and paid.

Summary of Costs by Functional Area

It is often informative to review costs by functional area, as defined by the SDSS Work Breakdown Structure, or WBS. Table 4 summarizes actual in-kind contributions and cash expenses by functional area and illustrates the distribution of costs associated with such activities as Survey Management, Observing Systems, Data Processing and Distribution, and Observatory Operations.

Table 4. Summary of Actual Costs by Functional Area (\$K)

Functional Area	In-kind Contributions	Cash Expenditures	Total Cost	Portion of Total Cost
Survey Management	917	1,318	2,235	8.5%
Collaboration Affairs	0	59	59	0.2%
Observing Systems Support	3,280	3,865	7,145	27.3%
Data Processing & Distribution	5,205	3,566	8,771	33.5%
Observatory Operations	0	7,390	7,390	28.2%
ARC Corporate Support	0	538	538	2.1%
Contingency	0	25	25	0.1%
Capital Improvements	0	43	43	0.2%
Total	9,402	16,804	26,206	100.0%

Summary of Grant Payments Received

Grant Number 99-12-1 authorized payments totaling \$10,000,000 to support the observational period of the Sloan Digital Sky Survey. Table 5 compares the payment schedule defined in the grant to actual payments received by the Astrophysical Research Consortium. All grant payments were received in accordance with the payment schedule.

Table 5. Summary of Payments on Grant 99-12-1

Payment Schedule		Payments Received	
December 1999	$3,000,000	15-Dec-1999	$3,000,000
December 2000	$2,000,000	21-Dec-2000	$2,000,000
December 2001	$2,000,000	19-Dec-2001	$2,000,000
December 2002	$2,000,000	25-Nov-2002	$2,000,000
December 2003	$1,000,000	26-Nov-2003	$1,000,000

Expenditures Made using Grant Funds

Grant funds were managed by the Astrophysical Research Consortium. They were used to pay for the fully-loaded salary costs (salary plus benefits) of individuals working on infrastructure tasks at the participating institutions. The work performed was described in the proposal and captured and tracked under formal agreements between the Astrophysical Research Consortium and the participating institutions. Grant funds were also used to pay for travel expenses associated with infrastructure work, and for materials, supplies, machine shop services, electronics, and computer hardware as required.

Grant funds were not used to fund research, nor were they used to pay down invoices incurred during the construction phase of the project. They were used solely for the purpose described in Chapter 6 of the grant proposal.

Appendix A. Scientific and Technical Publications

The following list represents the definitive list of SDSS papers submitted to peer-reviewed journals. The list is organized into four categories:

- *Scientific Publications* are based on analyses of, or presentations of, the SDSS data.
- *Data Release Papers* describe the specific process for each data release.
- *Technical Papers* describe the SDSS instrumentation, calibration, software, strategy, and targeting algorithms. Technical papers may include some SDSS data for illustrative purposes.
- *Other Publications Based on SDSS Data* is a list of publications in journals and astro-ph which use SDSS data, but which were written outside the collaboration.

An online version of the list is available through the SDSS web site (http://www.sdss.org/publications/index.html).

Title	First Author	astro-ph	Journal
Scientific Publications			
A Snapshot Survey for Gravitational Lenses Among z>=4.0 Quasars: II. The $4.0 < z < 5.4$ Sample	G. Richards		AJ submitted
Bivariate Galaxy Luminosity Functions in the Sloan Digital Sky Survey	N. Ball	0507547	MNRAS submitted
SDSSJ102111.02+491330.4: A Newly Discovered Gravitational Lensed Quasar	B. Pindor		AJ accepted
Ultracompact AM CVn Binaries from the Sloan Digital Sky Survey: Three Candidates Plus the First Confirmed Eclipsing System	S. Anderson	0506730	AJ submitted
Quantitative Morphology of Galaxies from the SDSS I: Luminosity in Bulges and Disks	L. Tasca	0507249	MNRAS submitted
Ellipticity of Dark Matter Halos with Galaxy Weak Lensing	R. Mandelbaum	0507108	MNRAS submitted
SDSS J0246-0825: A New Gravitationally Lensed Quasar from the Sloan Digital Sky Survey	N. Inada	0506631	AJ accepted
Fourier Phase Analysis of SDSS Galaxies	C. Hikage	0506194	PASJ submitted
The SDSS View of the Palomar-Green Bright Quasar Survey	S. Jester	0506022	AJ 130:873 (2005)
New Low Accretion-Rate Magnetic Binary Systems and thier Significance for the Evolution of Cataclysmic Variables	G.D. Schmidt	0505385	ApJ accepted
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Magnetic White Dwarfs from the SDSS II. The Second and Third Data Releases	K. Vanlandingham	0505085	AJ 130:734 ff(2005)

Title	First Author	astro-ph	Journal
Dark Matter and Stellar Mass in the Luminous Regions of Disk Galaxies	J. Pizagno	0504581	ApJ submitted
Topology Analysis of the Sloan Digital Sky Survey: I. Scale and Luminosity Dependences	C. Park	0507059	ApJ accepted
Eleven New DAVs from the Sloan Survey	F. Mullally	0502520	ApJ 625:966 (2005)
The Color Selection of Quasars from Redshifts 5 to 10: Cloning and Discovery	K. Chiu	0504001	AJ 130:13 (2005)
Binary Quasars in the Sloan Digital Sky Survey: Evidence for Excess Clustering on Small Scales	J. Hennawi	0504535	AJ submitted
Detection of Cosmic Magnification with the Sloan Digital Sky Survey	R. Scranton	0504510	AJ accepted
Spectral Variability of Quasars in the Sloan Digital Sky Survey. I: Wavelength Dependence	B. Wilhite	0504309	ApJ accepted
Detection of the Baryon Acoustic Peak in the Large-Scale Correlation Function of SDSS Luminous Red Galaxies	D. Eisenstein	0501171	ApJ submitted
The Nature of Nearby Counterparts to Intermediate Redshift Luminous Compact Blue Galaxies. II CO Observations	C. Garland	0502055	ApJ 624:714 (2005)
Cataclysmic Variables from SDSS IV. 2003 Year	P. Szkody		AJ 129:2386 (2005)
Systematic Errors in Weak Lensing: Application to SDSS Galaxy-Galaxy Weak Lensing	R. Mandelbaum	0501201	MNRAS 361:1287 (2005)
SDSS ~J210014.12+004446.0: A New Dwarf Nova with Quiescent Superhumps?	J. Tramposch	0501178	PASP 117:262 (2005)
The SDSS u-band Galaxy Survey: Luminosity Functions and Evolution	I. Baldry	0501110	MNRAS 358:441 (2005)
Active Galactic Nuclei in the Sloan Digital Sky Survey: II. Emission-Line Luminosity Function	L. Hao	0501042	AJ 129:1795 (2005)
Active Galactic Nuclei in the Sloan Digital Sky Survey: I. Sample Selection	L. Hao	0501059	AJ 129:1783 (2005)
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An Empirical Calibration of the Completeness of the SDSS Quasar Survey	D. Vanden Berk	0501113	AJ 129:2047 (2005)
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Title	First Author	astro-ph	Journal
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The Intermediate-Scale Clustering of Luminous Red Galaxies	I. Zehavi	0411557	ApJ 621:22 (2005)
The Small-Scale Clustering of Luminous Red Galaxies via Cross-Correlation Techniques	D. Eisenstein	0411559	ApJ 619:178 (2005)
Cosmic Homogeneity Demonstrated with Luminous Red Galaxies	D. Hogg	0411197	ApJ 624:54 (2005)
XMM-Newton and optical follow-up observations of three new Polars from the Sloan Digital Sky Survey	L. Homer	0411175	ApJ 620:929 (2005)
Rotation Velocities of Two Low Luminosity Field Galaxies	J. Pizagno	0410672	ApJL submitted
A Comprehensive Model for the Monoceros Tidal Stream	J. Penarrubia	0410448	ApJ 626:128 (2005)
Colors, Magnitudes and Velocity Dispersions in Early-Type Galaxies: Implications for Galaxy Ages and Metallicities	M. Bernardi	0409571	AJ (2005)
The Linear Theory Power Spectrum from the Lyman-alpha Forest in the Sloan Digital Sky Survey	P. McDonald	0407377	ApJ submitted
The Nature of Nearby Counterparts to Intermediate Redshift Luminous Compact Blue Galaxies I. Optical/H I Properties and Dynamical Masses	C. Garland	0407438	ApJ 615:689 (2004)
A New Milky Way Companion: Unusual Globular Cluster or Extreme Dwarf Satellite?	B. Willman	0410416	AJ 129:2692 (2005)
Candidate Type II Quasars from the SDSS: III. Spectropolarimetry Reveals Hidden Type I Nuclei	N. Zakamska	0410054	AJ 129:1212 (2005)
Correlating the CMB with Luminous Red Galaxies: The Integrated Sachs-Wolfe Effect	N. Padmanabhan	0410630	Phys.Rev.D submitted
XMM-Newton Observations of the Extremely Low Accretion Rate Polars SDSSJ155331.12+551614.5 and SDSSJ132411.57+032050.5	P. Szkody	0409718	AJ 128:2443 (2004)
Discovery of Two Gravitationally Lensed Quasars with Image Separations of 3 Arcseconds from the Sloan Digital Sky Survey	M. Oguri	0411250	ApJ 622:106(2005)
NYU-VAGC: A Galaxy Catalog Based on New Public Surveys	M. Blanton	0410166	AJ 129:2562 (2005)

Title	First Author	astro-ph	Journal
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The Properties and Luminosity Function of Extremely Low Luminosity Field Galaxies	M. Blanton	0410164	ApJ accepted
The Environmental Dependence of Galaxy Properties in the Local Universe: Dependence on Luminosity, Local Density, and System Richness	M. Tanaka	0411132	AJ 128:2677 (2004)
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The Luminosity and Color Dependence of the Galaxy Correlation Function	I. Zehavi	0408569	ApJ submitted
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Efficient Photometric Selection of Quasars from the Sloan Digital Sky Survey: 100000 z<3 Quasars from Data Release One	G. Richards	0408505	ApJS 155:257 (2004)
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Cosmological Parameter Analysis Including SDSS Ly-alpha Forest and Galaxy Bias: Constraints on the Primordial Spectrum of Fluctuations, Neutrino Mass, and Dark Energy	U. Seljak	0407372	Phys.Rev.D71 103515 (2005)
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Dust Reddening in SDSS Quasars	P. Hopkins	0406293	AJ 128:1112 (2004)
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Cross-correlation of CMB with large-scale structure: weak gravitational lensing	C. Hirata	0406004	Phys.RevD70 103501 (2004)
Discovery of New Ultracool White Dwarfs in the Sloan Digital Sky Survey	E. Gates	0405566	ApJL 612:129 (2004)
Cataclysmic Variables from SDSS III. The Third Year	P. Szkody	0407071	AJ 128:1882 (2004)
A Survey of z>5.7 Quasars in the Sloan Digital Sky Survey III: Discovery of Five Additional Quasars	X. Fan	0405138	AJ 128:515 (2004)
The Lyman-alpha Forest Power Spectrum from the Sloan Digital Sky Survey	P. McDonald	0405013	ApJ submitted
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Andromeda IX: A New Dwarf Spheroidal Satellite of M31	D. Zucker	0404268	ApJL 612:121 (2004)
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A Catalog of Spectroscopically Identified White Dwarf Stars in the First Data Release of the Sloan Digital Sky Survey	S. Kleinman	0402209	ApJ 607:426 (2004)
Near-Infrared Photometry and Spectroscopy of L and T Dwarfs: the Effects of Temperature, Clouds, and Gravity	G. Knapp	0402451	AJ 127:3553 (2004)
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The Environmental Dependence of the Relations between Stellar Mass, Structure, Star Formation and Nuclear Activity in Galaxies	G. Kauffmann	0402030	MNRAS 347:731 (2004)

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The H alpha Luminosity Function of Morphologically Classified Galaxies in the Sloan Digital Sky Survey	O. Nakamura	0312519	AJ 127:2511 (2004)
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A Gravitationally Lensed Quasar with Quadruple Images Separated by 14.62 Arcseconds	N. Inada	0312427	Nature 426:810 (2003)
The Physical Properties of Star Forming galaxies in the Low Redshift Universe	J. Brinchmann	0311060	MNRAS 351:1151 (2004)
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Cosmological Parameters from Eigenmode Analysis of Sloan Digital Sky Survey	A. Pope	0401249	ApJ 607:655 (2004)
Faint High-Latitude Carbon Stars Discovered by the Sloan Digital Sky Survey: An Initial Catalog	R. Downes	0402118	AJ 127:2838 (2004)
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The Luminosity Function of Void Galaxies in the Sloan Digital Sky Survey	F. Hoyle	0309728	ApJ 620:618 (2005)
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An Improved Proper Motion Catalog Combining USNO-B and SDSS	J. Munn		AJ 127:3034 (2004)
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A Map of the Universe	J.R. Gott	0310571	ApJ 624:463 (2005)
Blue Horizontal Branch Stars in the Sloan Digital Sky Survey: II. Kinematics of the Galactic Halo	E. Sirko	0311325	AJ 127:914 (2004)
Blue Horizontal Branch Stars in the Sloan Digital Sky Survey: I. Sample Selection and Structure in the Galactic Halo	E. Sirko	0311324	AJ 127:899 (2004)
Detection of Intergalactic HeII Absorption at Redshift 3.5	W. Zheng	0312176	AJ 127:656 (2004)

Title	First Author	astro-ph	Journal
A Lyman-Alpha-Only AGN from the Sloan Digital Sky Survey	P. Hall	0402648	AJ 127:3146 (2004)
SDSS J15517.35+6346220.0: A Newly Discovered Gravitationally Lensed Quasar	B. Pindor	0312176	AJ 127:1318 (2004)
The Morphology-Density Relatin in the Sloan Digital Sky Survey	T. Goto	0312043	MNRAS 346:601 (2003)
VLT + UVES Spectroscopy of the Low-Ionization Intrinsic Absorber in SDSS J001130.56+005550.7	D. Hutsemekers	0311026	A&A 415:77 (2004)
Sloan Digital Sky Survey Spectroscopic Lens Search: I. Discover of Intermediate-Redshift Star-Forming Galaxies Behind Foreground Luminous Red Galaxies	A. Bolton	0311055	AJ 127:1860 (2004)
Relationship Between Environment and the Broad-Band Optical Properties of Galaxies in the SDSS	M. Blanton	0310453	ApJ 629:143 (2005)
The Ensemble Photometric Variability of ~2500 Quasars in the Sloan Digital Sky Survey	D. Vanden Berk	0310336	ApJ 601:692 (2003)
A Snapshot Survey for Gravitational Lenses Among z>=4.0 Quasars: I. The z>5.7 Sample	G. Richards	0309274	AJ 127:1305 (2004)
Halos Around the Edge-On Disk Galaxies in the SDSS	S. Zibetti	0309623	MNRAS 347:556 (2004)
Sagittarius Tidal Debris 90 kpc from the Galactic Center	H. Newberg	0309162	ApJL 596:191 (2003)
Continuum and Emission Line Properties of Broad Absorption Line Quasars	T. Reichard	0308508	AJ 126:2594 (2003)
The Extended Tails of Palomar 5: A Ten egree Arc of Globular Cluster Tidal Debris	M. Odenkirchen	0307446	AJ 126:2385 (2003)
The Sloan Digital Sky Survey Quasar Catalog II. First Data Release	D.P. Schneider	0308443	AJ 126:2579 (2003)
Fifteen DO, PG 1159 and Related White Dwarf Stars in the SDSS, Including Two DO Stars with Ultra-High Excitation Ion Lines	J. Krzesinski		A&A 417:1093 (2004)
The Dependence on Environment of the Color--Magnitude Relation of Galaxies	D. Hogg	0307336	ApJL 601:29 (2004)
Physical Evidence for Dark Energy	R. Scranton	0307335	Phys Rev Lett, submitted
SDSS J0903+5028: A New Gravitational Lens	D. Johnston	0307371	AJ 126:2281 (2003)
Stellar and Dynamical Masses of Ellipticals in the Sloan Digital Sky Survey	N. Padmanabhan	0307082	New Astronomy 9(5):329 (2004)
Photometric Properties of Void Galaxies in the Sloan Digital Sky Survey	R. Rojas	0307274	ApJ 617:50 (2004)

Title	First Author	astro-ph	Journal
The Three-Dimensional Power Spectrum of Galaxies from the Sloan Digital Sky Survey	M. Tegmark	0310725	ApJ 606:702 (2004)
Discovery of Eight New Extremely Metal-Poor Galaxies in the Sloan Digital Sky Survey	A. Kniazev	0307401	ApJL 593:73 (2003)
Magnetic White Dwarfs from the SDSS. The First Data Release	G. Schmidt	0307121	ApJ 595:1101 (2003)
Star Formation Rate Indicators in the Sloan Digital Sky Survey	A. Hopkins	0306621	ApJ 599:971 (2003)
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A Merged Catalog of Clusters of Galaxies from Early SDSS Data	N. Bahcall	0305202	ApJS 148:243 (2003)
Cataclysmic Variables from SDSS II. The Second Year	P. Szkody	0306269	AJ 126:1499 (2003)
Investingating the SDSS Cataclysmic Variable SDSS J132723.39+652854.2	M. Wolfe	0305607	PASP 115:1118 (2003)
A Large, Uniform Sample of X-ray Emitting AGNs: Selection Approach and an Initial Catalog from the ROSAT All-Sky and Sloan Digital Sky Surveys	S. Anderson	0305093	AJ 126:2209 (2003)
An Initial Survey of White Dwarfs in the Sloan Digital Sky Survey	H. Harris	0305347	AJ 126:1023 (2003)
Minkowski Functionals of SDSS Galaxies I: Analysis of Excursion Sets	C. Hikage	0304455	PASJ 55:911 (2003)
The Host Galaxies of AGN	G. Kauffmann	0304239	MNRAS 346:1055 (2003)
Candidate Type II Quasars from the Sloan Digital Sky Survey: I. Selection and Optical Properties of a Sample at 0.3<Z<>	N. Zakamska	0309551	AJ 126:2125 (2003)
Galaxy Types in the Sloan Digital Sky Survey Using Supervised Artifical Neural Networks	N. Ball	0306390	MNRAS 348(3):L1038 (2004)
Double-Peaked Low-Ionization Emission Lines in Active Galactic Nuclei	I. Strateva	0303279	AJ 126:1720 (2003)
SDSS White Dwarfs with Spectra Showing Atomic Oxygen and/or Carbon Lines	J. Liebert		AJ 126:2521 (2003)
Selection and Photometric Properties of K+A Galaxies	A. Quintero	0307074	ApJ 602:109 (2004)
The Environment of Passive Spiral Galaxies in the SDSS	T. Goto	0301303	PASJ 55:757 (2003)
The Size Distribution of Galaxies in the Sloan Digital Sky Survey	S. Shen	0301527	MNRAS 343:978 (2003)
The Velocity Dispersion Function of Early-Type Galaxies	R. Sheth	0303092	ApJ 594:225 (2003)

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On Departures from a Power Law in the Galaxy Correlation Function	I. Zehavi	0301280	ApJ 608:16 (2004)
The Near-IR Properties and Contiuum Shape of High Redshift Quasars from the Sloan Digital Sky Survey	L. Pentericci	0308178	A&A, 410:75 (2003)
VLT+UVES Spectroscopy of the CaII LoBAL Quasar SDSS 0300+0048	P. Hall	0301480	ApJ 593:189 (2003)
Observing the Dark Matter Density Profile of Isolated Galaxies	F. Prada	0301360	ApJ 598:260 (2003)
A Low Latitude Halo Stream around the Milky Way	B. Yanny	0301029	ApJ 588:824 (2003)
Angular Clustering with Photometric Redshifts in the Sloan Digital Sky Survey: Bimodality in the Clustering Properties of Galaxies	T. Budavari	0305603	ApJ 595:59 (2003)
A Survey of z>5.7 Quasars in the Sloan Digital Sky Survey II: Discovery of Three Additional Quasars at z>6	X. Fan	0301135	AJ 125:1649 (2003)
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The Sloan Digital Sky Survey: The Cosmic Spectrum and Star-Formation History	K. Glazebrook	0301005	ApJ 587:55 (2003)
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Determining the Lensing Fractions of SDSS Quasars: Methods and Results from the EDR	B. Pindor	0301464	AJ 125:2325 (2003)
Average Spectra of Massive Galaxies in the SDSS	D. Eisenstein	0212087	ApJ 585:594 (2003)
SDSS Catalog of Stars in the Draco Dwarf Spheroidal Galaxy	H. Rave	0301185	ApJS 145:245 (2003)
A Catalog of Broad Absorption Line Quasars from the Sloan Digital Sky Survey Early Data Release	T. Reichard	0301019	AJ 125:1711 (2003)
Selection of Metal-Poor Giant Stars using the Sloan Digital Sky Survey Photometric System	A. Helmi	0211562	ApJ 586:195 (2003)
The Galaxy Luminosity Function and Luminosity Density at Redshift z=<0.1	M. Blanton	0210215	ApJ 592:819 (2003)
Luminosity Function of Morphologically Classified Galaxies in the SDSS Survey	O. Nakamura	0212405	AJ 125:1682 (2003)
Three-Dimensional Genus Statistics of Galaxies in the SDSS Early Data Release	C. Hikage	0207377	PASJ 54:707 (2002)

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A Matched-Filter Analysis of the Tidal Tails Around the Globular Cluster Palomar 5	C. Rockosi		AJ 124:349 (2002)
Color Confirmation of Asteroid Families	Z. Ivezic	0208098	AJ, 124:2943 (2002)
A First Look at White - M dwarf Pairs in SDSS	S. Raymond	0302405	AJ 125:2621 (2003)
The Broadband Optical Properties of Galaxies with Redshifts 0.2 < z < 0.22	M. Blanton	0209479	ApJ 594:186 (2003)
The Application of Photometric Redshifts to the SDSS Early Data Release	I. Csabai	0211080	AJ 125:580 (2003)
Galaxy Star-Formation as a Function of Environment in the Early Data Release of the Sloan Digital Sky Survey	P. Gomez	0210193	ApJ 584:210 (2003)
Two Rare Magnetic Cataclysmic Variables with Extreme Cyclotron Features Identified in the Sloan Digital Sky Survey	P. Szkody	0208241	ApJ 583:902 (2003)
Two-Dimensional Topology of the Sloan Digital Sky Survey	F. Hoyle	0206146	ApJ 580:663 (2002)
The Cluster Mass Function from Early SDSS Data: Cosmological Implications	N. Bahcall	0205490	ApJ 585:182 (2003)
The Redshift of the Lensing Galaxy in PMN J0134-0931	P. Hall	0207317	ApJL 575:51, (2002)
SDSS J092455.87+021924.9: an Interesting Gravitationally Lensed Quasar from the Sloan Digital Sky Survey	N. Inada	0304377	AJ 126:666 (2003)
Kinematic Study of the Disrupting Globular Cluster Palomar 5 using VLT Spectra	M. Odenkirchen	0206276	AJ 124:1497 (2002)
The Dependence of Star Formation History and Internal Structure on Stellar Mass for 80,000 Low Redshift Galaxies	G. Kauffmann	0205070	MNRAS 341:54 (2003)
A Feature at z ~ 3.2 in the Evolution of the Ly-alpha Forest Optical Depth	M. Bernardi	0206293	AJ 125:32 (2003)
Stellar Masses and Star Formation Histories for 80,000 Galaxies from the Sloan Digital Sky Survey	G. Kauffmann	0204055	MNRAS 341:33 (2003)
Cosmological Information from Quasar-Galaxy Correlations induced by Weak Lensing	B. Menard	0203163	A&A 386:784 (2002)
Faint High Latitude Carbon Stars Discovered by the Sloan Digital Sky Survey: Methods and Initial Results	B. Margon	0206413	AJ 124:1651 (2002)
Composite Luminosity Functions of the Sloan Digital Sky Survey Cut and Enhance Galaxy Cluster Catalog	T. Goto	0205413	PASJ 54:515 (2002)

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Comparison of Positions and Magnitudes of Asteroids Observed in the Sloan Digital Sky Survey with those Predicted for Known Asteroids	M. Juric	0202468	AJ 124:1776 (2002)
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Higher Order Moments of the Angular Distribution of Galaxies	I. Szapudi	0111058	ApJ 570:75 (2002)
Early-type Galaxies in the SDSS IV: Colors and Chemical Evolution	M. Bernardi	0301629	AJ 125:1882 (2003)
Early-type Galaxies in the SDSS III: The Fundamental Plane	M. Bernardi	0301626	AJ 125:1866 (2003)
Early-type Galaxies in the SDSS II: Correlations between observables	M. Bernardi	0301624	AJ, 125:1849 (2003)
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The Sloan Digital Sky Survey Quasar Catalog I. Early Data Release	D. Schneider	0110629	AJ 123:567 (2002)
The Angular Clustering of Galaxy Pairs	L. Infante	0111019	ApJ 567:155 (2002)

Title	First Author	astro-ph	Journal
L Dwarfs Found in Sloan Digital Sky Survey Commissioning Data II. Hobby-Eberly Telescope Observations	D. Schneider	0110273	AJ 123:458 (2002)
The Ghost of Sagittarius and Lumps in the Halo of the Milky Way	H. Newberg	0111095	ApJ569:245 (2002)
The Cut & Enhance method: Selecting Clusters of Galaxies from the SDSS Commissioning Data	T. Goto	0112482	AJ 123:1807 (2002)
Towards Spectral Classification of L and T Dwarfs: Infrared and Optical Spectroscopy and Analysis	T. Geballe	0108443	ApJ 564:466 (2002)
Infrared Photometry of Late M, L, and T Dwarfs	S. Leggett	0108435	ApJ 564:452 (2002)
New insights on the Draco dwarf spheroidal galaxy from SDSS: a larger radius and no tidal tails	M. Odenkirchen	0108100	AJ 122:2538 (2001)
Evidence for Reionization at z~6: Detection of a Gunn-Peterson Trough in a z=6.28 Quasar	R. Becker	0108097	AJ 122:2850 (2001)
A Survey of z>5.8 Quasars in the Sloan Digital Sky Survey I: Discovery of Three New Quasars and the Spatial Density of Luminous Quasars at z~6	X. Fan	0108063	AJ 122:2833 (2001)
Galaxy Mass and Luminosity Scaling Laws Determined by Weak Gravitational Lensing	T. McKay	0108013	ApJ, submitted
The 3D Power Spectrum from Early SDSS Angular Clustering	S. Dodelson	0107421	ApJ 572:140 (2002)
KL Estimation of the Power Spectrum Parameters from the Angular Distribution of Galaxies in Early SDSS Data	A. Szalay	0107419	ApJ, 591:1 (2003)
The Angular Power Spectrum of Galaxies from Early SDSS Data	M. Tegmark	0107418	ApJ 571:191 (2002)
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Galaxy Clustering in Early SDSS Redshift Data	I. Zehavi	0106476	ApJ 571:172 (2002)
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Detecting Clusters of Galaxies in the Sloan Digital Sky Survey I: Monte Carlo Comparison of Cluster Detection Algorithms	R. Kim	0110259	AJ 123:20 (2002)
Photometric Redshifts of Quasars	G. Richards	0106038	AJ 122:1151 (2001)
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Solar System Objects Observed in the SDSS Commissioning Data	Z. Ivezic	0105511	AJ 122:2749 (2001)
Statistical Properties of Bright Galaxies in the SDSS Photometric System	K. Shimasaku	0105401	AJ 122:1238 (2001)
Composite Quasar Spectra From the Sloan Digital Sky Survey	D. Vanden Berk	0105231	AJ 122:549 (2001)
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A New Very Cool White Dwarf Discovered by the Sloan Digital Sky Survey	H. Harris	0101021	ApJL 549:109 (2001)
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Discovery of a Pair of z=4.25 Quasars from the Sloan Digital Sky Survey	D. Schneider	0008401	AJ 120:2183 (2000)
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The Discovery of a Luminous z=5.80 Quasar from the Sloan Digital Sky Survey	X. Fan	0005414	AJ 120:1167 (2000)
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The Low Resolution Spectrograph of the Hobby-Eberly Telescope II. Observations of Quasar Candidates from the Sloan Digital Sky Survey	D. Schneider	9910306	PASP 112:6 (2000)
The Discovery of a High-Redshift Quasar without Emission Lines from Sloan Digital Sky Survey Commissioning Data	X. Fan	9910001	ApJL 526:57 (1999)
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Data Release Papers

The Fourth Data Release of the Sloan Digital Sky Survey	J. Adelman-McCarthy, et al	0507711	ApJS submitted
The Third Data Release of the Sloan Digital Sky Survey	K. Abazajian, et al	0410239	AJ 129:1755 (2005)
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Astrometric Calibration of the Sloan Digital Sky Survey	J. Pier	0211375	AJ 125:1559 (2003)
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Near-Infrared Imaging of 222 Nearby Hdelta-Strong Galaxies from the SDSS	M. Balogh	0503639	MNRAS 360:587 (2005)
Correlations between nebular emission in SDSS galaxies and the continuum spectral shape	Z. Gyõry		AJ submitted
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Mg II Absorption Systems in SDSS QSO Spectra	D. Nestor	0410493	ApJ 628:637 2005)
Strong Ca II Absorption Lines in the Reddened Quasar SDSS J2339-0912: Evidence of the Collision/Merger in the Host Galaxy?	T. Wang	0504319	ApJ 626:657 (2005)
Imaging of SDSS z>6 Quasar Fields: Gravitation Lensing, Companion Galaxies, and the Host Dark Matter Halos	C. Willott	0503202	ApJ 626:657 (2005)

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The Luminosity Dependence of the Type 1 AGN Fraction	C. Simpson	0503500	MNRAS 360:565 (2005)
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Correlations between Nebular Emission in SDSS Galaxies and the Continuum Spectral Shape	Z. Gyory		AJ submitted
Constraining the Photometric Properties of MgII absorbing galaxies with the SDSS	S. Zibetti		ApJL submitted
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On Statistical Lensing and the Anticorrelation between 2dF QSOs and Foreground Galaxies	A. Myers	0502481	MNRAS 359:1022 (2005)
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The 2dF-SDSS LRG and QSO Survey: The $z<2.1$ Quasar Luminosity Function from 5645 Quasars to $g=21.85$	G. Richards	0504300	MNRAS 360:825 (2005)
A Simple Test for the Existence of two Accretion Modes in Active Galactic Nuclei	S. Jester	0502394	ApJ 625:667 (2005)
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Velocity Dispersion of 335 Galaxy Clusters Selected from the Sloan Digital Sky Survey: Statistical Evidence for Dynamical Interaction, and Against Ram-Pressure Stripping	T. Goto	0503089	MNRAS 359:1415 (2005)
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The Mass Function of Void Galaxies in the Sloan Digital Sky Survey Data Release 2	D. Goldberg	0406527	ApJL 621:6435 (2005)
The C4 Clustering Algorithm: Clusters of Galaxies in the Sloan Digital Sky Survey	C. Miller	0503713	AJ 130:968 (2005)
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The Dependence of Galaxy Shape on Luminosity and Surface Brightness Profile	R. Vincent	0501221	ApJ 623:137 (2005)
Peering through the OH-forest: a new technique to remove residual sky features from SDSS spectra	V. Wild	0501460	MNRAS 358:1083 (2005)
Specific Star Formation Rates to Redshift 1.5	A. Bauer	0412358	ApJL 621:89 (2005)
GMOS Integral Field Spectroscopy of a Merging System with Enhanced Balmer Absorption	M. Swinbank	0412088	ApJ 622:260 (2005)
Recent Star Formation in Nearby Galaxies from Galaxy Evolution Explorer Imaging: M101 and M51	L. Bianchi	0411408	ApJL 619:71 (2005)
The Properties of ultraviolet-Luminous Galaxies at the Current Epoch	T. Heckman	0412577	ApJL 619:35 (2005)
X-ray Bright Optically Inactive Galaxies (XBONG) in XMM-Newton/SDSS fields: more diluted than absorbed?	I. Georgantopoulos	0412335	MNRAS 358:131 (2005)
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Semi-Empirical Analysis of SDSS Galaxies: I. Spectral Synthesis Method	R. Fernandes	0412481	MNRAS 358:363 (2005)
A New Search for Features in the Primordial Power Spectrum	D.Tocchini-Valentini	0402583	MNRAS 359:31 (2005)
On the Incidence and Kinematics of Strong Mg II Abosrbers	G. Prochter	0411776	ApJ submitted
Do star formation rates of galaxy clusters depend on mass?: blue/late-type fractions, total star formation rates of 115 galaxy clusters as a function of cluster virial mass	T. Goto	0411517	MNRAS 356:L6 (2005)
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Systematics of the Ultraviolet Rising Flux in a GALEX/SDSS Sample of Early-Type Galaxies	R. Rich	0411356	ApJL 619:107 (2005)
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Optical Follow-up of BL Lac Candidates in the 2BL Sample	R. Nesci	0501493	A&A 434:895 (2005)
On the use of Photometric Redshifts for X-Ray Selected AGNs	S. Kitsionas	0406346	A&A 434:475 (2005)
Identification of 13 DB + dM and 2 DC + dM binaries from the Sloan Digital Sky Survey	E.J.M. van den Besselaar	0503491	A&A 434:L13 (2005)
XMM-Newton Observations of Optically Selected Sloan Digital Sky Survey Clusters	M. Plionis	0410293	ApJL 622:17 (2005)
Chandra-SDSS Normal and Star-Forming Galaxies I: X-ray Source Properties of Galaxies Detected by Chandra in SDSS DR2	A. Hornschemeier	0410669	AJ 129:86 (2005)
Toward Understanding Environmental Effects in SDSS Clusters	J. Einasto	0411235	A&A 439:45 (2005)

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The Ultraviolet Luminosity Function of GALEX Galaxies at Photometric Redshifts between 0.07 and 0.25	T. Budavari	0411305	ApJL 619:31 (2005)
Sloan Digital Sky Survey Quasars in the SWIRE ELAIS N1 Field: Properties and Spectral Energy Distributions	E. Hatziminaoglou	0410620	AJ 129:1198 (2005)
A 2D Analysis of Percolation and Filamentarity in the SDSS DR1	B. Pandey	0409616	MNRAS 357:1068 (2005)
QSO Lensing Magnification by Galaxies and Galxy Groups	A. Guimaraes	0409484	MNRAS accepted
The First XMM-Newton Study of Two Narrow-Line Seyfert 1 Galaxies Discovered in the Sloan Digital Survey	L. Foschini	0408123	A&A 428:51 (2004)
Anomalously low PAH emission from low-luminosity galaxies	D. Hogg	0408420	ApJ 624:162 (2005)
Dwarf Seyfert 1 Nuclei and the Low-Mass End of the M-sigma Relation	A. Barth	0412575	ApJL 619:151 (2005)
Galaxy evolution Explorer Ultraviolet Color-Magnitude Relations and Evidence of Recent Star Formation in Early-Type Galaxies	S. Yi		ApJL 619:111 (2005)
New Constraints on the Star Formation Histories and Dust Attenuation of Galaxies in the Local Universe from GALEX	S. Salim	0411354	ApJL 619:39 (2005)
The Galaxy Luminosity Function from M_R=-25 to M_R=-9	N. Trentham	0412124	MNRAS 357:783 (2005)
Relation between Starlight and Nebular Emission Lines of Star-Forming Galaxies	H. Lu		Chin.J.Astron.Astrophys 5:221 (2005)
The Origin of Infrared Emission from the Infrared Luminous Galaxy NGC 4418	L. Shi		Chin.J.Astron.Astrophys 5:117 (2005)
The Hybrid Natue of 0846+51W1: A BL Lac Object with a Narrow Line Seyfert 1 Nucleus	H. Zhou	0411252	Chin.J.Astron.Astrophys 5:41 (2005)
X-ray Insights Into Interpreting CIV Blueshifts and Optical/UV Continua	S. Gallagher	0410641	ApJ accepted
Estimating Photometric Redshifts Using Support Vector Machines	Y. Wadadekar	0412005	PASP 117:79(2005)
The scale-dependence of relative galaxy bias: encouragement for the "halo model" description	M. Blanton	0411037	ApJ submitted
Hard X-ray Emitting Active Galactic Nuclei Selected by the Chandra Multi-Wavelength Project	J. Silverman	0409337	ApJ 618:123 (2005)

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Effects of Triaxiality on the Statistics of Large-Separation Gravitational Lenses	M. Oguri	0410172	ApJ 610:663 (2004)
Empirical Modeling of the Stellar Spectrum of Galaxies	C. Li	0407015	AJ 129:669 (2005)
A Quasar without Broad Lya Emission	P. Hall	0405239	AJ 128:534 (2004)
Metals and Dust in Intermediate-redshift Damped Lyman Alpha Systems	P. Khare	0408139	ApJ 616:86 (2004)
The X-Ray Spectrum of the z=6.30 QSO SDSS J1030+0524	D. Farrah	0406561	ApJL 611:13 (2004)
The LEDA Galaxy Distribution I. Maps of the Local Universe	H. Courtois	0403545	A&A 423:27 (2004)
A Catalogue of the Chandra Deep Field South with Multi-colour Classification and Photometric Redshifts from COMBO-17	C. Wolf	0403666	A&A 421:913 (2004)
Chandra Observations of X-Ray-Weak Narrow-Line Seyfert 1 Galaxies	R. Williams	0402236	ApJ 610:737 (2004)
Active Galactic Nuclei with Candidate Intermediate-Mass Blcack Holes	J. Greene	0404110	ApJ 610:722 (2004)
Ionizing radiation fluctuations and large-scale structure in the Lyman-alpha forest	R. Croft	0310890	ApJ 610:642 (2004)
The Transverse Proximity Effect: A Probe to the Environment, Anisotropy, and Megayear Variability of QSOs	M. Schirber	0307563	ApJ 610:105 (2004)
Redshifted 21 Centimeter Signatures around the Highest Redshift Quasars	J.S. Wyithe	0401554	ApJ 610:117 (2004)
Double-Damped Lyman Alpha Absorption: A Possible Large Neutral Hydrogen Gas Filament Near Redshift z=1	D. Turnshek	0404609	ApJL 609:53 (2004)
The Dark Side of the Halo Occupation Distribution	A. Kravtsov	0308519	ApJ 609:35 (2004)
On the Environmental Dependence of the Cluster Galaxy Timescale	C. Carretero	0405512	ApJL 609:45 (2004)
Photometric Determination of R$_{200}$ for SDSS Galaxy Clusters	S. Hansen	0410467	ApJ submitted
A Catalog of Very Isolated Galaxies from the SDSS Data Release One	S. Allam	0410172	AJ 129:2062 (2005)
Radio Continuum Imaging of FIR Luminous QSOs at z>6	C. Carilli	0406279	AJ 128:997 (2004)
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The Far and Mid-Infrared/Radio correlations in the Spitzer Extragalactic First Look Survey	P. Appleton	0406030	ApJS 154:147 (2004)
Obscured and Unobscured Active Galactic Nuclei in the Spitzer Space Telescope First Look Survey	M. Lacy	0405604	ApJS 154:166 (2004)
Re-Defining the Empirical ZZ Cetyi Instability Strip	A. Mukadam	0405591	ApJ 612:1052 (2004)
High Speed Photometry of SDSS J013701.06-091234.9	M. Pretorius	0405202	MNRAS 352:1056 (2004)
Linking Gas Fractions to Bimodalities in Galaxy Properties	S. Kannappan	0405136	ApJL 611:89 (2004)
Constraints from Gravitational Recoil on the Growth of Supermassive Black Holes at High Redshift	Z. Haiman	0404196	ApJ 613:36 (2004)
Dust-Reddening and Gravitational Lensing of SDSS QSOs due to Foreground Damped Lyman-Alpha Systems	M. Murphy	0405472	MNRAS accepted
The Clustering of Luminous Red Galaxies Around MgII Absorbers	N. Bouche	0408468	MNRAS Lett accepted
Anisotropic Distribution of SDSS Satellite Galaxies: Planar (not Polar) Alignment	T. Brainerd	0408559	ApJL submitted
New Colour-transformations for the Sloan Photometry and Revised Metallicity Calibration and equations for Photometry and Parallax Estimation	S. Karaali	0407253	PASA accepted
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The Clustering of Active Galactic Nuclei in the Sloan Digital Sky Survey	D. Wake	0406357	ApJL 610:85(2004)
The Environment of Low Surface Brightness Galaxies	S. Rosenbaum	0406205	A&A 422:L5 (2004)
XXM Cluster Survey: Automated X-ray Source Identification using the Sloan Digital Sky Survey	K. Land	0405225	MNRAS submitted
Redshift Distortions in One-dimensional Power Spectra	V. Desjacques	0401544	MNRAS 351:1395 (2004)
High-speed photometry of faint cataclysmic variables - IV. V356 Aql, Aqr1, FIRST J1023+0038, Ha 0242-2802, GI Mon, AO Oct, V972 Oph, SDSS 0155+00, SDSS 0233+00, SDSS 1240-01, SDSS 1556-00, SDSS 2050-05, FH Ser	P. Woudt	0403435	MNRAS 351:1015 (2004)
The XMM-Newton/2dF survey - IV. The X-ray Spectral Properties of the Hard Sources	I. Georgantopoulos	0404048	MNRAS 352:91 (2004)

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Second Order General Slow-Roll Power Spectrum	J. Choe	0405155	JCAP07(2004)012
Gravitational Lensing Magnification without Multiple Imaging	C. Keeton	0405143	ApJ 621:559 (20050
Present-Day Growth of Black Holes and Bulges: the SDSS Perspective	T. Heckman	0406218	ApJ accepted
Candidate Type II Quasars from the Sloan Digital Sky Survey: II. From Radio to X-Rays	N. Zakamska	0406248	AJ 128:1002 (2004)
Optical and Infrared Color Distributions In Nearby Early-Type Galaxies and the Implied Age and Metallicity Gradients	H. Wu	0404266	ApJ 622:244 (2005)
Specific Star Formation Rates to Redshift 1.5	A. Bauer	0412358	ApJL 621:894 (2005)
Detections of the 2175 Å Dust Feature at 1.4z 1.5 from the Sloan Digital Sky Survey	J. Wang	0404151	ApJ 609:589 (2004)
High-Speed Photometry of SDSS J013701.06 - 091234.9	M. Pretorius	0405202	MNRAS 352:1056 (2004)
The cosmic evolution of low-luminosity radio sources from the SDSS DR1	L. Clewley	0405080	MNRAS 352:909 (2004)
Mass distribution of DA white dwarfs in the First Data Release of the Sloan Digital Sky Survey	J. Madej	0404344	A&A 419:L5 (2004)
Theoretical Isochrones in Several Photometric Ssystems II. The Sloan Digital Sky Survey ugriz System	L. Girardi	0404358	A&A 422:205 (2004)
A Helium White Dwarf of Extremely Low Mass	J. Liebert	0404291	ApJL 606:147 (2004)
What Drives the Balmer Extinction Sequence in Spiral Galaxies? Clues from the Sloan Digital Sky Survey	G. Stasinska	0403531	A&A 420:475 (2004)
Observational Constraints on Cosmic Strings: Bayesian Analysis in a Three Dimensional Parameter Space	L. Pogosian	0403268	JCAP09(2004)008
Comments on the Redshift Distribution of 44,200 SDSS Quasars: Evidence for Predicted Preferred Redshifts?	M. Bell	0403089	ApJL submitted
A Halo Approach to the Evaluation of the Cross-Correlation between the SZ Sky and the Galaxy Survey	Y. Qu	0402366	A&A 423:21 (2004)
Optical and Infrared Color Distributions in Nearby Early-Type Galaxies and the Implied Age and Metallicity Gradients	H. Wu	0404226	ApJ, submitted
Baryonic Conversion Tree: The Global Assembly of Stars and Dark Matter in Galaxies from the SDSS	R. Jimenez	0403294	MNRAS 356:495 (2005)

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The Star-Formation History of the Universe from the Stellar Populations of Nearby Galaxies /td>	A. Heavens	0403293	Nature 428:625 (2004)
The Bimodal Galaxy Color Distribution: Dependence on Luminosity and Environment	M. Balogh	0406266	ApJL 615:101 (2004)
Color-Induced Displacement Double Stars in SDSS	D. Pourbaix	0403219	A&A 423:755 (2004)
Nitrogen-Enriched Quasars in the Sloan Digital Sky Survey First Data Release	M. Bentz	0403205	AJ 128:561 (2004)
Detection of X-ray Clusters of Galaxies by Matching RASS Photons and SDSS Galaxies withing GAVO	P. Schuecker	0403116	A&A 420:61 (2004)
The SDSS Damped Lya Survey: Data Release One	J. Prochaska	0403391	PASP 116, 821:622 (2004)
A Second Stellar Color Locus: A Bridge from White Dwarfs to M Stars	V. Smolcic	0403218	ApJL 615:141 (2004)
A Search for Nitrogen-Enriched Quasars in the Sloan Digital Sky Survey Early Data Release	M. Bentz	0308486	AJ 127:576 (2004)
Photometric Redshifts with the Multilayer Perceptron Neural Network: Application to the HDF-S and SDSS	E. Vanzella	0312064	A&A 423:761 (2004)
The Search for Galaxy Clustering around a Quasar Pair at z=4.25 Found in the Sloan Digital Sky Survey	M. Fukugita	0312521	ApJL 603:65 (2004)
The XMM-Newton/2dF Survey - III. Comparison Between Optical and X-ray Cluster Detection Methods	S. Basilakos	0310136	MNRAS 351:989 (2004)
Actively Star-forming Elliptical Galaxies at Low redshifts in the Sloan Digital Sky Survey	M. Fukugita	0312518	ApJL 601:127 (2004)
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Title	First Author	astro-ph	Journal
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